STANDARD OPERATING PROCEDURE

FOR

ROUTINE OPERATION OF THE RUPPRECHT & PATASHNICK SERIES 5400 AMBIENT CARBON PARTICULATE MONITOR IN CRPAQS

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1. SCOPE AND APPLICABILITY

The Series 5400 Ambient Carbon Particulate Monitor, or OC/EC, is capable of characterizing the carbon content of suspended particulate matter on an automated basis. The instrument performs a thermal CO_2 analysis to determine the amount of organic and soot carbon (in $\mu g/m^3$) present in a collected particulate sample.

In CRPAQS, the Series 5400 monitor samples ambient air for one hour and then performs an analysis to determine the concentration of carbon in the collected sample. A size-selective inlet with a 2.5 μm cutoff will be placed on the inlet of the Series 5400. The sampling and analysis procedures are performed 24 hours a day.

2. SUMMARY OF METHOD

The Series 5400 monitor employs a direct measurement approach to determine the concentration of carbon in particulate matter suspended in ambient air. Using a non-disperse infrared (NDIR) CO_2 detector, the instrument measures the amount of CO_2 released when a sample collected in a collector is oxidized at elevated temperatures. This value is directly related to the amount of carbon oxidized in the collector and, together with the volume sampled, is used to determine the concentration ($\mu g/m^3$) of carbon in the ambient air during the sampling period.

The instrument cycle is composed of two main steps: the collection phase during which the sample is gathered in a collector and the analysis phase during which the entire collector with its collected particulate matter is elevated in temperature to achieve oxidation. The analysis phase takes approximately one hour for a procedure involving an intermediate and final temperature plateau. To avoid gaps in the collection of particulate matter, the instrument contains two collectors. While the monitor uses one for the collection phase of the current instrument cycle, the other is used for the analysis phase of the previous instrument cycle. To minimize the formation of unwanted artifacts during sample collection, the collectors consist of impactors instead of filters.

During the analysis phase of the instrument cycle, the collector containing the particulate sample becomes part of a closed gas circulating loop that includes an afterburner, circulating pump, and NDIR CO_2 sensor. Before raising the temperature of the collector, the instrument measures the CO_2 concentration in the closed analysis loop as a base line for later measurements. The temperature of the collector is then raised to 275 ^oC for a period of 300 seconds, during which the instrument measures the CO_2 concentration in the analysis loop. A final burn of 360 seconds at 750 ^oC then takes place to burn off the high-temperature carbon that was not oxidized at the lower temperature. An afterburner, positioned immediately following the collector, heats the gas stream to 750 ^oC during the analysis phase to burn any lighter carbonaceous materials that may have escaped from the collector when oxidized. The instrument reports carbon concentration for the low temperature carbon, which is primarily composed of organic carbon, as

MC3 in $\mu g/m^3$. The total carbon concentration of the sample, composed of both elemental and organic carbon, is reported as MCF in $\mu g/m^3$.

At the end of each instrument cycle, the monitor purges the closed loop to prepare it for the analysis phase of the next instrument cycle performed using the other collector. During this step, it purges the closed loop with filtered ambient air taken through the inlet port on the back of the instrument. This purge reestablishes the concentrations of CO_2 and O_2 to ambient levels. The instrument measures the CO_2 concentration of the purge air flow, and the value provides a snapshot of the ambient CO_2 concentration.

3. DEFINITIONS

All words typed in bold, capital letters throughout this document refer to labels on the instrument front or back panel.

DAS = Data Acquisition System

EC = Elemental carbon = Soot or black carbon: These terms are used interchangeably throughout the SOP. They all refer to pure carbon in contrast to carbon bond into an organic molecule.

LPM = liters per minute

MSDS = Material Safety Data Sheets

OC = Organic Carbon: This term refers to molecules that contain a carbon backbone along with other elements, such as hydrogen, oxygen, or nitrogen.

OC/EC = The Ambient Carbon Particulate Monitor is also referred to as the OC/EC since this is what it monitors.

OD = Outer Diameter

PPM = Parts Per Million

Soft keys = This term refers to the function keys (F1-F5) located just below the instrument display. These keys have various functions depending on the display screen.

SOP = Standard Operating Procedure

4. HEALTH & SAFETY WARNINGS

The OC/EC operates on high voltage, 240 V. Exercise extreme caution when maintaining or repairing any component of the instrument. High voltage may be present in all instrument enclosures.

The inside of the OC/EC contains many hot surfaces because of the high temperatures used in the analysis. Be careful not to touch any of these surfaces.

High pressure gas cylinders are used to calibrate the Series 5400. Make sure the tanks are properly secured at all times. Read all MSDS that come with these gases.

5. CAUTIONS

The user must take extreme care to ensure that no foreign matter is permitted to drop into the instrument by way of the sample tube inlet on the top of the instrument. Always cover this opening when it is not connected to the sample tubing.

Inside the instrument enclosure, most of the instrument components are mounted on a bulkhead, which is attached to rails at its top and bottom. The user can slide the bulkhead out of the enclosure to facilitate maintenance and service activities. The user must attach the service support brackets provided with the monitor before sliding out the bulkhead. Failure to do so may result in the instrument tipping over.

The OC/EC must be installed in a weather-sheltered location that is kept at a moderate temperature at all times. The monitor must be placed in a well-ventilated position. The OC/EC requires a dedicated circuit with a minimum of 10 Amps, and a separate circuit should power the pump.

6. INTERFERENCE

The OC/EC requires at least 236 V power to operate properly. If this power requirement is not met, the afterburner temperature will not attain its set point. In addition to generating an instrument error, this problem will throw off the timing of the cycles.

7. PERSONNEL QUALIFICATIONS

This SOP along with the instrument manual should be adequate in training personnel to operate the Ambient Carbon Particulate Monitor.

8. APPARATUS & MATERIALS

- Model 5400 complete with pump and accessories package.
- Cyclone with 2.5 μm cut-off for the inlet. Generally this is achieved with a PM_{10} impactor mounted in series with a $PM_{2.5}$ cyclone.

- Calibration gas cylinders: CO_2 free air, low concentration CO_2 (e.g., 400 ppm ± 1%), high concentration CO_2 (e.g., 2500 ppm ± 1%).
- Low pressure regulators for each of the three gas cylinders (e.g. Matheson 8-2-590 and 8-2-580).
- Flexible 3/8" O.D. tubing to connect the gas cylinders to the back of the instrument.
- Approximately 20 feet of 3/8" O.D. green flexible nylon tubing to connect ambient air to the back of the instrument to purge the closed loop at the end of each instrument cycle.
- Approximately 20 feet of conductive (e.g. metal or conductive polymer), 1/2" O.D. tubing to pipe outside ambient air into the top inlet of the analyzer for particulate analysis.
- A data acquisition system.
- Data cables to connect the Series 5400 to the data acquisition system.
- A voltmeter, various wrenches, hex keys, screwdrivers, and a tube cutter.

9. SITE & EQUIPMENT PREPARATION

- Off site equipment acceptance
  - Inspect the instrument for any damage. Remove all protective plugs from the fittings on the rear and top of the instrument and look for any indications of damage.
- Off-site pre-deployment equipment test
  - Locate the in-line filter assembly with the clear blue casing. One end of the filter should have a male, quick-disconnect fitting and the other, a plastic, push connector. Attach the quick disconnect fitting on this filter to the inlet labeled **AIR** on the back of the instrument. Note that the arrow on the side of the filter indicating the direction of flow is actually pointed in the opposite direction. Air will flow into the instrument from this port, opposite the direction of the arrow. Attach the 20 feet of 3/8" O.D. green nylon tubing to the push connector on the other end of the filter assembly. To remove this tubing for any reason, push in on the ring around the tubing while pulling out the tubing. Run this length of tubing through the ceiling to the outside air. Make sure that there is no possibility of water entering the tubing.
  - The second segment of green nylon tubing is used to connect the pump to the OC/EC. One end of the tubing should be inserted into the push connector outlet on the back of the instrument labeled **PUMP**. The other end should be inserted into the push connector inlet on the pump.
  - The three gas cylinders used for calibrating the Series 5400 must be plumbed to the instrument. The gas cylinders must be secured to the wall or table for safety. The gas regulators should be attached to each of the cylinders. Each of the outlets of the gas regulators should have a hose barb fitting on it. The inlets on the back of the OC/EC, labeled **N2**, **CO2 HIGH**, and **CO2 LOW**, have female quick disconnect

fittings. Find the male counterparts to these fittings, which have hose barbs on the other end, and connect them to each of the inlets. Connect 3/8" O.D. flexible tube from the hose barb fitting on the regulator to the hose barb fitting on the back of the OC/EC.

- Leak check the connections using the following method. Open the main valve of the regulator and adjust the delivery pressure to 2.5" gauge. Close the main valve, wait 2 hours and observe the delivery pressure reading. Check connections and fittings if the pressure has dropped below 2.4" gauge.
- Plug the OC/EC into an appropriate 240 V/10 A outlet.
- Turn on the instrument and allow it to warm up for 30 minutes. Do not turn on the pump at this time.
- Turn on the pump by plugging it into an appropriate electrical outlet. Note: Do not plug any pump into the same circuit as the DAS.
- Plug a RS232 data cable into the RS232 port on the front of the instrument and plug the other end of the cable into the assigned port of the Rocket Port Hardware.
- Setup the operating parameters using the Run Definition Screen, which can be entered by pressing the **F3:RunDef** softkey while in the Main Screen. Depress the **EDIT** key and edit the Run Definition Screen to display the following information. Use the arrow keys to move around the display. Press the **ENTER** key to save the edits.

Collection:	1 hr		Analysis Type:		Reg
Base Time:	00:00	P1:	0 C	D1:	0 sec
Coll Temp:	50 C	P2:	0 C	D2:	0 sec
ABurn Temp:	750 C	P3:	275 C	D3:	300 sec
ExtST Temp:	0 C	Pf:	750 C	Df:	360 sec
Coll Flow:	16.7 l/min				

- The protocol defined above will measure carbon on an hourly schedule in two burns (P3 and Pf), with dwell time of 5 and 6 minutes respectively. Note the aerosol sample is heated to 50 °C (Coll Temp: 50 C) so the sample will remain below the dew point temperature. Applying insulation or mildly heating the inlet line will also keep the sample from condensing onto the hardware internals in a foggy environment.
- From the main screen, set up additional operating parameters by pressing the **F5: Setup** soft button. Use the **EDIT** key to make changes. Use the arrow keys to move around the display. Press the **ENTER** key to save the edits.

A/S Temp:	25	25	Adjust Freq:	0 cyc
A/S Press:	1.00	1.00	Leak Check:	0 cyc
Smoothing:	YES			
Offset Adjust?:	NO			
Curr Time:	hh:mm:ss			
Curr Date:	dd-mmm-yy			

Note: that the above setup references sample flows, volumes, and concentrations to 25 °C and 1 atm pressure. Concentrations for other standard conditions or for actual conditions can be calculated retrospectively, if needed. An audit frequency of 0 disables automated audits of the CO_2 sensor. Automated calibrations should be attempted only after verifying that the gas delivery system has no leaks and that the audit results are stable.

- Check the software version and serial number for your instrument. In the Main Screen, press **F5:Setup** and then press **F3:System Info**. Note the entries in the instrument log.

  Software Version: 1.700, Jun 29 2000
  Unit Serial Number: 20286

  Note: The unit should be operated with the most recent version of R&P software (version 1.700). Contact R&P if the instrument displays an earlier software revision. Updated software can be downloaded from the R&P web site.

- Check that in the analog conversion variables are correct. In the Main Screen, press **F5:Setup** followed by **F1:Output** and **F1:A/O**. Set the parameters to the following values. Use the **EDIT** key to make changes. Use the arrow keys to move around the display. Press the **ENTER** key to save the edits.

	Variable	MinVal	MaxVal	Format
1	MC 3	0.00	50.00	0-1 VDC
2	MC Final	0.00	50.00	0-1 VDC
3	None	0.00	50.00	0-1 VDC

- Setup the communications parameters to allow automatic downloading of data from the OC/EC to the DAS. In the Main Screen, press **F5:Setup** followed by **F1:Output** and **F2:RS232**. Set the parameters to the following values. Use the **EDIT** key to make changes. Use the arrow keys to move around the display. Press the **ENTER** key to save the edits.

Protocol:	Cycle	RS-Para1:	0
Baud Rate:	9600	RS-Para2:	0
Data Bits:	8	RS-Para3:	0
Parity:	None	RS-Para4:	0
Stop Bits:	1	RS-Para5:	0
Flow Ctrl:	None	RS-Para6:	0

- Setup the parameters to be sent from the OC/EC to the DAS. In the Main Screen, press **F5:Setup** followed by **F1:Output**, **F2:RS232**, and **F2:SET PRC**. Set the parameters to the following values. The register codes found in parentheses are not viewed on this screen, but are included for completeness. See Appendix B of the user manual for a complete listing of system parameters. Use the **EDIT** key to make changes. Use the arrow keys to move around the display. Press the **ENTER** key to save the edits.

Data1:	Stat Code (6)	Data7:	Set Flow (77)
Data2:	MC3 (109)	Data8:	Samp Vol (117)
Data3:	MC Final (110)	Data9:	0
Data4:	ABurnA SP (61)	Data10:	0
Data5:	ABurnB SP (62)	Data11:	0
Data6:	Std Flow (75)	Data12:	0

- Record all of the settings that were just entered into the instrument log as they are shown on the displays. Make a photocopy of the settings and forward it to the Field Manager.
- Escape back to the Main Screen and press the **RUN/STOP** key. Press the **MENU** key and select Service Mode. The instrument should now display SVC in the upper right hand corner of the Main Screen. Depress the **MENU** key and press **F2:CO2 Cal**. Depress the **Menu** key and record information displayed for Sys Volume and CO_2 Sensor in the lab notebook. Depending on software version and hardware, the CO_2 sensor should indicate something like LiCor-Lin (Li-Cor sensor in linear calibration mode). If the display indicates LiCor-xxx, where xxx is not 'lin', enter edit mode and adjust to LiCor-lin. If the display indicates Astro-lin, or Astro-xxx, contact R&P for a replacement sensor.

Const1:	note this	CO2 Volts:	note this (~0.538)
Const2:	note this	CO2 FS%:	note this (~10.78)
Const3:	note this	CO2 ul:	note this (~51.7)
Sys Volume:	108.0	CO2 Pres:	note this (~1002.2)
CO2 Sensor:	LiCoPres	CO2 Low %:	note this (~0.040)
		CO2 High %:	note this (~0.250)

- Enter Edit mode using the **EDIT** key and change the CO_2 Low % and CO_2 High % to match concentrations on the calibration tanks. Note that 400 ppm and 2500 ppm equate to 0.040% and 0.250%, respectively. Press **ENTER** to save edits and press **ESC** to return to the Main Screen.
- Perform instrument calibrations as outlined, and in the order presented in Section 10, of the Operations Manual. They are listed in **Table 9.1**. Skip the CO_2 Calibration - Manual (Section 10.9) and CO_2 Calibration - Hardware (Section 10.10). Record the original and final settings, and the findings of each of the procedures in the instrument logbook. Save the calibration constants and make a note of them in the instrument logbook. NOTE: The mass flow meter calibration simply adjusts the display value to match the readings from the calibration device. It does not adjust the flow set point for the instrument. Flow through the Model 5400 is actually 'controlled' by the geometry of the impactors. Flow may start out near 17.5 LPM for new collectors, then decline over time as non-volatile material accumulates. If a specific flow rate is desired (i.e., less than initial flow), a needle valve or other restrictive device should be placed in-line between the pump and the instrument. Collectors should then be replaced when flow goes below the tolerance for the inlet device.

- Audit the OC/EC by completing the procedures listed in **Table 9.2** after the calibration procedures shown in **Table 9.1** are complete.

Table 9-1. Audit and calibration procedures for the R&P 5400 OC/EC instrument to be followed during acceptance.

Task	Audit/Calibration Procedure	Operating Manual Section	Approximate Time (mins)
1.	Analog I/O Calibration – Software	10.1	5
2.	Analog I/O Calibration – Hardware	10.2	5
3.	Collection Path Leak Test	10.3	5
4.	Flow Audit	10.4	5
5.	Flow Meter Calibration	10.5	10
6.	Analysis Loop Leak Test	10.6	25
7.	Temperature Circuit Calibration	10.7	25
8.	CO2 Calibration – Automatic	10.8 – F2	25
9.	Furnace Calibration	10.11	10
10.	Storage of Calibration Data	10.12	5

Table 9-2. Audit and calibration procedures for the R&P 5400 OC/EC instrument to be followed immediately after acceptance.

Task	Audit/Calibration Procedure	Operating Manual Section	Approximate Time (mins)
1.	1st follow-up CO2 Calibration – Automatic	10.8 – F2	25
2.	2nd follow-up CO2 Calibration – Automatic	10.8 – F2	25
3.	1st follow-up CO2 Calibration – Audit	10.8 – F3	25
4.	2nd follow-up CO2 Calibration – Audit	10.8 – F3	25

- Upon completion of all of the tasks in **Tables 9-1** and **Table 9-2**, depress the **Data** key to access calibration and audit results. Note that calibrations are denoted with CA and audits are denoted with AA, and that they are displayed most recent on top. Check that the constants C1, C2 and C3 for the calibrations and audits are as noted already in the instrument logbook. Calculate observed tank concentrations as shown below.

Zero air (ppm) = C1*Sys Volume*10^{-6}
CO2-Low (ppm) = C2*Sys Volume*10^{-6}
CO2-High (ppm) = C3*Sys Volume*10^{-6}

Compare the observed and actual tank concentrations for the final calibration and two audits. Mean concentrations should be within the acceptance ranges shown

below. Note that it may be necessary to use results from the last two audits if results from the first deviate significantly (>10 ppm or >±5%) from succeeding audits.

Zero air (ppm)	± 15 ppm
CO2-Lo (%)	± 3% of actual tank concentration
CO2-High (%)	± 2% of actual tank concentration

- Repeat the CO_2 Sensor Calibration if the acceptance criteria are not satisfied.
- Operational Testing. After completion of steps above, the instrument is ready to begin collection of data for operational testing. This mode of operation should last anywhere from four to seven days, but the longer the better.
- Exit the Service Mode and press the **Run/Stop** key. The unit should begin a cleaning cycle at this point and will display CLEAN in the upper right hand corner of the Main Screen. Turn on the sample pump. The instrument will begin sampling at the top of the next hour, provided the cleaning cycle is completed. Otherwise, it will wait until the next hour. Observe the instrument as it goes into sample mode. Verify that sample flows are nominal and that no status conditions are displayed. Observe 1-2 additional sample cycles to ensure proper operation.
- Allow the unit to run in automated sampling mode overnight until the next work period.
- Perform the operational tests listed in **Table 9-3** on the instrument for 3 sequential days (at minimum). Press the **Run/Stop** key to enter Service Mode. Record audit/check results and the two most recent constants C1, C2 and C3 in the instrument log book. Contact R&P if the unit fails the collection loop or analysis loop leak checks.

Table 9-3. Audit procedures for the R&P 5400 OC/EC instrument to be followed three consecutive days after acceptance.

Task	Audit/Calibration Procedure	Operating Manual Section	Approximate Time (mins)
1.	Collection Path Leak Test	10.3	5
2.	Flow Audit	10.4	5
3.	Analysis Loop Leak Test	10.6	25
4.	1st follow-up CO_2 Calibration – Audit	10.8 – F3	25
5.	2nd follow-up CO_2 Calibration – Audit	10.8 – F3	25

- Exit the Service Mode and escape back to the Main Screen. Depress the **Run/Stop** key to allow the 5400 to return to clean then sample mode.
- Audit data review. Compare audit results with the acceptance criteria listed below. Recalibrate the mass flow meter and/or the CO_2 sensor if acceptance criteria are not satisfied. Note that the results of the first CO_2 sensor audit may be rejected if not within tolerances.

Zero air, CO2-Low, CO2-High:	± 5% of actual tank concentration
Flow Audit:	Indicated Flow = Flow Cal. Device ±5%

Note: Flow cal. device must be corrected to mass if volumetric

- Data Review. Set Point data should be ingested into a spreadsheet program (e.g., EXCEL) for review on a daily basis. Key variables for review are: purge CO2 concentration, MC3 (organic carbon), MCF (total carbon), MCR3 (MC3 residual carbon) and MCRF (MCF residual carbon). There are no ironclad rules for acceptance of these data; however, they should satisfy a number of checks, as noted below.

  CO_2 Variability. Continental background CO_2 concentrations are on the order of 350 ppm. Unless the monitor is located in an urban core site, or extreme stagnation prevails, CO_2 concentrations should approach 350 ppm from time to time. Lowest concentrations (i.e.< 400 ppm) should occur during sunny, well-ventilated afternoons. Highest concentrations (i.e., >500 ppm) may occur during rush hours, nocturnal inversions, or as the result of nearby forest fires or wood burning. In any case, the general pattern should be one of lower concentrations during daylight hour than during nighttime hours. Contact R&P if CO_2 variability is not observed, or if CO_2 concentrations never fall below 400 ppm.

  OC/EC Variability. Continental background concentrations of OC and EC are on the order of 0.5-1 $\mu g/m^3$ and 0.05-0.2 $\mu g/m^3$, respectively. Under normal conditions, OC and EC will tend to vary with CO_2 concentrations. Under well-ventilated conditions, OC and EC should go below 2.0 $\mu g/m^3$ and 0.5 $\mu g/m^3$, even at urban sites. During rush hour or under nocturnal inversions, OC and EC can exceed 10 ug/m3. This should be the case, if CO_2 levels exceed 500 ppm.

  OC/EC Ratios. OC:EC ratios will generally be on the order of 3:1 to 4:1, but may approach 1:1 if diesel emissions or other sources with appreciable EC content are significant.

  MCR3 and MCRF Values. These are the concentrations derived from the residual burn stages. As noted earlier, they appear to reflect pressure/temperature changes in the CO_2 sensor, rather than bona fide CO_2 produced from combustion. MCR3 and MCRF should always be positive and on the order of 1-3 ug/m^3. They should be relatively invariant, as a function of purge CO_2, OC and TC. For example, variability in MCR3 should be less than 5 percent the variability in OC. Although less certain, field data suggest that MCR3 should be about 75 percent of MCRF. Negative values or values above 5 ug/m^3 may indicate a problem with the CO_2 sensor and should be reported to R&P.

- On-site equipment acceptance
  - The same procedure should be followed on-site as was followed off-site.
- On-site equipment installation

- The OC/EC will be placed on a sturdy table near a 240-volt power receptacle. The table should be at least 36" deep to permit the instrument bulkhead to be extended for maintenance and calibrations.
- The inlet tube on the top of the instrument should run directly upwards through the ceiling of the monitoring building. The inlet tubing should be as straight as possible and should not have any severe dents in it. Irregularities in the tubing may result in particles depositing on the tube walls.
- Attach 3/8" OD aluminum tubing to the top of the instrument and connect the cyclone to the top of the inlet. The cyclone should sample the ambient air at approximately six feet above the top of the roof.
- Vent the furnace gases outside of the building and away from the roof. The furnaces release enough heat to warm a 30-foot trailer. This increase of temperature might be difficult for the trailer heater to handle during cold seasons and has been seen to cause deficiencies in the operation of other instruments (i.e., TEI 42C/Y NOy instrument).
- Optional: Under hot, humid conditions, condensation can occur in the sampling line as the sample gas passes through the air conditioned environment of an air monitoring station. This should not be a problem at Angiola or Bakersfield under typical conditions, but as a precaution, the inlet tubing could be insulated. Pipe insulation is commonly available at hardware stores.

- On-site connection of equipment to data acquisition system
  - The Series 5400 is connected to the DAS using the RS232 port located in the lower left of the front of the instrument. The instrument has a nine pin female port, and thus requires a nine pine male connector.
- On-site connection of equipment to calibration system
  - External calibration system not used with OC/EC.
- On-site equipment test
  - The same procedure as was followed off-site should be followed on-site.

10. INSTRUMENT OR METHOD CALIBRATION

The OC/EC instrument will be audited on a monthly basis by following the tasks listed in **Table 10-1**.

Table 10-1. Audit procedures for the R&P 5400 OC/EC instrument.

Task	Audit/Calibration Procedure	Operating Manual Section	Approximate Time (mins)
1.	Collection Path Leak Test	10.3	5
2.	Flow Audit	10.4	5
3.	Analysis Loop Leak Test	10.6	25
4.	1st CO2 Calibration – Audit	10.8 – F3	25
5.	2nd CO2 Calibration – Audit	10.8 – F3	25

The OC/EC instrument will be calibrated on a quarterly basis by following the tasks listed in **Table 10-2**.

Table 10-2. Calibration procedures for the R&P 5400 OC/EC instrument.

Task	Audit/Calibration Procedure	Operating Manual Section	Approximate Time (mins)
1.	Analog I/O Calibration – Software	10.1	5
2.	Analog I/O Calibration – Hardware	10.2	5
3.	Flow Meter Calibration	10.5	10
4.	Temperature Circuit Calibration	10.7	25
5.	Furnace Calibration	10.11	10
6.	Storage of Calibration Data	10.12	5

11. SAMPLE COLLECTION OR INSTRUMENT OPERATION

Shutdown Procedure

It is important that the instrument is in the **READY** Operating Mode when it is turned off. Otherwise, the monitor will enter the Stop Operating Mode the next time the instrument is turned on.

Execute the following steps to turn off the Series 5400 monitor:

1. If the instrument is currently in the READY Operating Mode, skip to step 2. Otherwise, press **RUN/STOP** while in the RUN Operating Mode. In response to this command, the soft key functions change to three stop options. Choose the **EndCyc** option. This option will finish the current cycle being executed and enter the READY Operating Mode when it is finished. The operating mode displayed in the upper right hand corner of the Main Screen is RUN-C, indicating that the unit will stop operating at the end of the current instrument cycle.

2. Power down the instrument by pressing the power switch on the front face of the instrument.
3. Turn off the sample pump by unplugging it.

12. HANDLING & PRESERVATION OF SAMPLES

Not applicable.

13. SAMPLE PREPARATION

Not applicable.

14. PREVENTIVE MAINTENANCE & REPAIRS

Perform the maintenance procedures listed in **Table 14-1** at the frequency also noted in the table.

Table 14-1. Maintenance procedures for the R&P 5400 OC/EC instrument.

Task	Maintenance Procedure	Frequency	Operating Manual Section
1.	Clean R&P PM-2.5 inlet	1 month	Appx G-2
2.	Clean front intake filters	3 months	9.1
3.	Test batteries-exchange if necessary	6 months	9.2
4.	Exchange internal large in-line filter	12 months	9.3
5.	Exchange external large in-line filter	12 months	9.4
6.	Exchange collectors A and B	12 months	9.6
7.	Rebuild sample pump	18 months	Refer to rebuild kit
8.	Exchange furnace burners	As needed	9.7
9.	Exchange afterburner burners	As needed	9.8
10.	Exchange fuses	As needed	9.9

15. TROUBLESHOOTING

The R&P 5400 OC/EC instrument will report status codes with each measurement cycle. A status code of "OK" reports that the instrument has not failed any of its internal tests. When the code is not "OK", then the red light on the front of the instrument will also be lit. In the event of a non-critical error, the status light is turned on continuously. If a critical failure (VA or VB) occurs, the status light blinks to attract the user's attention. The status codes can be accessed in the following manners:

- During the current measurement cycle, the status code will be displayed in the top left-hand corner of the instrument screen. An explanation of the status code can be displayed by depressing the **F1:StCode** button.
- The status codes from prior measurements are shown by first depressing the **F4:Data** button and progressing through the data archive by pressing **F1: -cycle** or **F2: +cycle.** The status code is displayed in the bottom left-hand corner of the instrument screen. An explanation of the status code can be displayed by depressing the **F3:Status** button.

The R&P 5400 Service Manual has detailed troubleshooting guides. If a status code is displayed on the current measurement cycle or in prior measurement cycles, consult **Table 15-1** to determine which troubleshooting guide should be followed.

All troubleshooting should be noted in the instrument logbook, including the time the instrument was taken offline and placed back online, the type of maintenance or troubleshooting that was performed on the instrument, and the audit results that verified the instrument error was fixed.

Table 15-1. Troubleshooting guidance for the R&P 5400 OC/EC instrument.

Status Code	Error Type	Service Manual Section
OK	No errors	N/A
FA/FB	Filter Temperature error	2.2.1
AA/AB	Afterburner Temperature error	2.2.2
VA/VB	Trumpet Valve Movement error	2.2.3
E	External Sample Tube error	2.2.4
LA/LB	Analysis Loop Leak	2.2.5
C	Audit Failure	2.2.7
Y	Power Reset	2.2.8
Z	Power Failure	2.2.9
M	Flash Memory error	2.2.10
S	Serial Port error	2.2.12
X	AC Voltage Out of Bounds	2.2.13
H	CO_2 Meter Out of Range – High	2.2.14
L	CO_2 Meter Out of Range – Low	2.2.15
W	Sampled Volume Out of Bounds	2.2.16

16. DATA ACQUISITION, CALCULATIONS, AND DATA REDUCTION

Not applicable.

17. COMPUTER HARDWARE & SOFTWARE

The OC/EC allows the user to monitor the state of the instrument in great detail. There are several different screens that can be accessed to observe various operating parameters starting with the overall state of the instrument to the states of the individual components. The instrument software is described in more detail in Section 4 of the instrument manual.

The operating mode of the Series 5400 is displayed in the upper right hand corner of the Main Menu screen. The different operating modes are described in Section 5.4 of the Series 5400 manual.

The Operating Statistic Screen displays additional operating information about the Series 5400 monitor. From the Main Screen, press **F2:Stats** and then **F2:OpStats** to enter this screen. The information displayed on the Operating Statistics Screen is described in Section 6.3 of the Series 5400 manual.

The instrument cycle of the OC/EC contains over 20 individual steps. The current states of collectors A and B are displayed in the Filter Statistics Screen. The Filter Statistics Screen can be viewed by pressing the softkey **F2:Stats** when in the main screen, followed by **F2:OpStats** and **F2:FltStat**. Each of the individual steps is described in Section 2.4 of the Series 5400 manual. This screen also displays several other values pertinent to the sample collection and analysis. Each of the displayed variables is defined in Section 6.2 of the Series 5400 manual.

18. DATA MANAGEMENT & RECORDS MANAGEMENT

Refer to CRPAQS Data Management Plan.

Task Table 1: R & P OCEC Quick Reference Sheet.

(Detailed procedures and troubleshooting for each task follow the Task Table 1 and are listed by task number. ME = measurement expert, FM = field manager)

Task		Performance statistic	Section of SOP or Manual		Frequency	Time	Worksheet
			Additional task guidance	Additional troubleshooting guidance [1]			
1	**Weekly Maintenance**						
	Check for errors	No errors	Manual	FM	Weekly	5 min	No
	Check run definitions	See worksheet	SOP	FM	Weekly	15 min	Yes
2	**Monthly maintenance**						
	Maintain inlet cyclone	Clean, no blockages, dry	Task 2	Check for obstructions at instrument inlet and nozzle and clean	Monthly	15 min	Yes
	Check/clean fan filters	Clean filters	Task 2, Manual	Clean with water and let air-dry	Monthly	10 min	Yes
	Check internal filter	N/A	Task 2, Manual	N/A	Monthly	5 min	Yes
3	**Monthly system audits**						
	Concentration Audit	+/- 5% of cylinder concentrations	Task 3	FM	Monthly	45 min	Yes
	Flow audit	+/- 5% of 16.7 LPM	Task 3	FM	Monthly	20 min	Yes

[1] Key to abbreviations: FM = CRPAQS Field Manager
ME = CRPAQS Measurement Expert

Quick Reference Sheet

Task 1: Weekly Maintenance

Task 1a: Check run definitions

Obtain a Task 1 worksheet and record the date, your name, and the instrument serial number in the given spaces. Using an auxiliary clock, record the Data Acquisition System time and OC/EC time for comparison. If the time differs by more than 5 minutes, contact the Field Manager.

The Run Definition Screen is entered from the Main Menu by pressing the **F3:RunDef** softkey. Record the values for the given parameters in the spaces provided. If any parameter differs from the values shown below, contact the Field Manager

Collection:	1 hr		Analysis Type:		Reg
Base Time:	00:00	P1:	0 C	D1:	0 sec
Coll Temp:	50 C	P2:	0 C	D2:	0 sec
ABurn Temp:	750 C	P3:	275 C	D3:	300 sec
ExtST Temp:	0 C	Pf:	750 C	Df:	360 sec
Coll Flow:	16.7 l/min				

Task 1b: Check for errors

The status codes from prior measurements are shown by first pressing the **F4:Data** button in the main screen and progressing through the data archive by pressing **F1: -cycle** or **F2: +cycle**. The status code is displayed in the bottom left-hand corner of the instrument screen. An explanation of the status code can be displayed by depressing the **F3:Status** button. Record the error code with the corresponding date and time in the section provided near the bottom of the Task 1 worksheet. Check all archived records since Task 1b was last completed. Pressing the **ESC** button returns the user to the main screen.

The R&P 5400 Service Manual has detailed troubleshooting guides. If a status code is displayed on the current measurement cycle or in prior measurement cycles, consult **Table 15-1** to determine which troubleshooting guide to follow. Notify the field manager of persistent errors.

Task Table 1b. Troubleshooting guidance for the R&P 5400 OC/EC instrument.

Status Code	Error Type	Service Manual Section
OK	No errors	N/A
FA/FB	Filter Temperature error	2.2.1
AA/AB	Afterburner Temperature error	2.2.2
VA/VB	Trumpet Valve Movement error	2.2.3
E	External Sample Tube error	2.2.4
LA/LB	Analysis Loop Leak	2.2.5
C	Audit Failure	2.2.7
Y	Power Reset	2.2.8
Z	Power Failure	2.2.9
M	Flash Memory error	2.2.10
S	Serial Port error	2.2.12
X	AC Voltage Out of Bounds	2.2.13
H	CO_2 Meter Out of Range – High	2.2.14
L	CO_2 Meter Out of Range – Low	2.2.15
W	Sampled Volume Out of Bounds	2.2.16

Also, scroll through the data archive using the **F1: -cycle** or **F2: +cycle** buttons to assure reasonable data were recorded every sampling hour. Record sample segments reporting no data (typically shown as MC3 = 0 µg/m3 and MCf = 0 µg/m3) or measurements obviously out of range (e.g., negative values). Check all archived records since Task 1b was last completed. Notify the field manager of any such unreasonable values.

Task 2: Monthly Maintenance

Task 2a: Maintain instrument cyclone

The R&P OC/EC uses a compound impactor / cyclone that consists of a PM_{10} impactor with a $PM_{2.5}$ cyclone adapter. Perform the following tasks to maintain the impactor / cyclone system.

PM_{10} impactor

- Disassemble the upper and lower inlet halves by unscrewing the two pieces counter-clockwise. Mark the top plate deflector cone and lower plate with a pencil to allow for easier reassembly. Remove the four pan head screws from the top plate, lift the top plate, and set aside. Remove the insect screens from the lower plate assembly.
- Inspect and clean the insect screen by rinsing with water. Shake liquid from screen.

- Inspect and clean the acceleration nozzle. Use a cotton swab and soapy water to remove contamination from the acceleration nozzle. Inspect the large diameter impactor nozzle o-ring for wear (brittle or cracked). Replace, if necessary, and apply a thin film of high vacuum grease to the o-ring and aluminum threads. Reinstall the insect screen, align the top plate with the lower plate markings, insert and retighten the four pan head screws.
- Inspect and clean the lower collection plate. This is where most of the contamination will be found. Use a cotton paper towel/swab and soapy water to clean the collector assembly walls, vent tubes, and bottom side of the collector assembly.
- Inspect and clean the weep hole and moisture trap. The weep hole is where moisture runs out to the moisture trap. The moisture trap is the glass jar for collecting water or particulate matter. If the moisture trap contains water, unscrew it from the cover, dump out any water, wipe it clean with a towel, apply a thin layer of high vacuum grease on the cork gasket inside of the cap, and reattach it.
- Inspect the o-rings at the part of the impactor that attaches to the inlet tubing. Check that the o-rings are not dry, brittle, or cracked. If they are simply dry, place a thin layer of high vacuum grease on the $PM_{2.5}$ cyclone adapter where it fits into the PM_{10} impactor. If the o-rings are brittle or cracked, replace them.
- Reassemble the top and bottom inlet halves carefully to hand-tight.

$PM_{2.5}$ cyclone

- The $PM_{2.5}$ cyclone adapter has two stainless steel sections that must be removed and cleaned. The sections are located on opposite sides of the cyclone.
- The first section is a small plug that can be unscrewed by hand. Wipe dust from the small plug with a towel.
- The other section is a vertical arm attached to the main body at two points. This section is secured with gaskets and must be pulled off with a back-and-forth action. Once this piece is removed, there is another plug at the top junction point that must be unscrewed. Both of these pieces should be cleaned with a towel.
- Check that the o-rings are not dry, brittle, or cracked. If they are simply dry, place a thin layer of high vacuum grease on the section of the adapter where the o-rings are before reassembling the system. If the o-rings are brittle or cracked, it is likely that they will leak. Replace them and then apply a thin layer of high vacuum grease on the section of the adapter where the o-rings are before reassembling the system. Apply a thin layer of high vacuum grease to the section of the inlet tubing that fits into the $PM_{2.5}$ cyclone and to the cyclone top where the PM_{10} impactor mounts.
- Place the $PM_{2.5}$ cyclone on the inlet tube. Place the PM_{10} impactor on the $PM_{2.5}$ cyclone so that the impactor / cyclone system is ready for operation.

Task 2b: Check / clean fan filters

The air intake filters on the instrument front panel clean the air before being drawn into the instrument by the cooling fans. Open the instrument front panel before removing filters to prevent dust from being drawn into the instrument. Snap off fan covers enclosing the air intake filters on the instrument front panel. Remove the filters and wash with soapy water. Shake liquid from filter and allow time to dry. Reinstall the filters by placing them in their proper position and snapping the covers into place. Close instrument panel.

Task 2c: Check internal filter

The purpose of the large internal in-line filter is to protect the flow controller from contamination. It is essential that this filter always be installed when the OC/EC is operating. Although R&P estimates that this filter requires changing once a year, a monthly check is needed considering the dirty environments prevalent during the CRPAQS project.

CAUTION: The electronics located on the right side of the bulkhead are 240VAC. Remain clear from the electronics even when the power is off as some capacitors may retain their charge for some time.

- The OC/EC must first be put into Ready mode before powering down. If the OC/EC is currently in Ready mode, power down the instrument by pressing the power switch on the OC/EC front panel to off. If the OC/EC is not in Ready mode, press **Run/Stop** followed by **F1: Immed** to put into Ready mode immediately, or **F2: EndCyc** so that the current sample cycle will complete without interruption. Once the OC/EC is in Ready mode, power down the instrument.
- The bulkhead must next be pulled out into its full outward position as to gain access to the filter on the right side, near the bottom back of the bulkhead. The OC/EC must be secured by attaching the service support brackets to each side. Failure to attach the brackets could result in damage to the instrument, as it will suddenly tip forward when the bulkhead is pulled out.
- Unscrew the sample tube (located at the top left of the bulkhead) from the splitter and position the nut to allow clearance for the bulkhead to slide out.
- Examine the right side of the bulkhead near the bottom front and locate the captive pin (closest to user) and the captive screw (farthest from user). Unscrew the captive screw and pull the captive pin out. Slowly move the bulkhead forward to its fully outward position (the third captive pin locking position). Note: Some models have an additional captive screw located at the rear of the bulkhead.
- Locate the in-line internal filter on the lower right side of the bulkhead, near the bulkhead back. Remove the tubing from the intake side of the filter. Remove the filter from the intake side of the mass flow controller. Remove any fittings from both ends of the used filter and install them on the new filter.

- Install the new filter ensuring that the direction of the airflow opposes the arrow on the filter (filter arrow should point away from the controller). Note: Airflow travels from the tube, through the filter, and into the mass flow controller.
- Depress the lock tabs on the bulkhead top and bottom, pull out the captive pin, and slowly push in the bulkhead. Position the sample tube nut as to not impede the bulkhead motion. Secure the bulkhead by screwing in the captive screw once the bulkhead is restored to its normal operational position.
- Attach the sample tube to the splitter and power up the monitor.
- **Perform a Collection Path Leak Test.** Press **MENU**, down arrow to the Service Mode option, press **ENTER**, press **F4: Yes** to assure that you want to enter the Service Mode, down arrow to Calibration/Audit, and press **F4: Flow Cal** to enter the Flow Calibration menu.
- Press **F1: On/Off** to initiate flow through the OC/EC. The flow rate is shown on the right side of the screen where it reads 'Cur: XX.XX' where XX.XX in the flow rate in liters per minute.
- Remove the roof inlet from the 1 1/4" tubing. Apply a thin layer of high vacuum grease to the tubing to assure a leak free fit, and attach the flow audit adapter. Turn the valve on the flow audit adapter to prevent gas from entering the inlet tube. Return to the OC/EC and note the flow in the log. If the flow exceeds 0±0.15 LPM, check the connections at the newly installed internal in-inline filter and consult the service manual if additional guidance is necessary.
- Once the Collection Path Leak Test criteria is met (0±0.15 LPM), press **F1: On/Off** to shut off the flow, press **ESC**, arrow down to Exit Service Mode, and press **ENTER** to return to the main menu.
- Remove the flow audit adapter, and restore the sample inlet to its original configuration.
- Start the next sample cycle by pressing the **Run/Stop** button on the OC/EC front panel.

Task 3: Monthly System Audits

Task 3a: Flow audit

- Obtain a Task 3 worksheet and record the date, your name, and the instrument serial number in the given spaces. Using an auxiliary clock, record the Data Acquisition System time and OC/EC time. If the time differs by more than 5 minutes, contact the Field Manager.
- Record the current ambient conditions using an external thermometer and barometer. Convert the measurements to K and mmHg using:

$$T(K) = T(C) + 273.15$$
$$P\ (mmHg) = P\ (inHg) \times 25.4 = P\ (mb) \times 0.75$$

- Calculate the ratio of STP to ambient conditions using the STP conditions for the OC/EC mass flow meter and the current temperature and pressure. STP for the OC/EC Series 5400 is 273.15K and 760 mmHg.

  STP to ambient conditions ratio = 273.15(K) x P (mmHg) / 760 (mmHg) / T (K)

- Record the system audit start time in the appropriate worksheet space.
- If the OC/EC is not in Ready mode, press **Run/Stop** followed by **F1: Immed** to put into Ready mode immediately, **or F2: EndCyc** so that the current sample cycle will complete without interruption.
- Once in Ready mode, press **MENU**, down arrow to the Service Mode option, press **ENTER**, press **F4: Yes** to assure that you want to enter the Service Mode, down arrow to Calibration/Audit, and press **F4: Flow Cal** to enter the Flow Calibration menu.
- **Press F1: On/Off** to initiate flow through the OC/EC. The flow rate is shown on the right side of the screen where it reads 'Cur: XX.XX' where XX.XX in the flow rate in liters per minute.
- Record three instrument flowrates (as seen on the instrument display). Attach a BIOS 40DCL to the adapter using the rubber tubing provided with the BIOS and record the serial number on the worksheet. **Important:** Use a BIOS 40DCL or another primary flow standard to perform this task. If a primary flow standard is not available, contact STI and **do not** perform this task until one is available.

  Flow with cyclone – Record the instrument flow before removing the cyclone.
  Flow with BIOS attached – Remove the cyclone and attach the flow audit adapter. To attach the BIOS, remove the cyclones, put a new thin layer of grease on the adapter to assure a leak free fit, attach the audit adapter to the inlet, and attach a BIOS hose to the audit adapter. Place the BIOS on a horizontal surface level with the top of the inlet, making sure that the BIOS hose does not crimp. You can use a ladder. Record the instrument flow after this has been done.
  Flow with adapter set to zero – Adjust the audit adapter valve to stop air-flow to the instrument. When a stable reading is obtained, record the instrument flowrate.

- Record several BIOS flowrates (as seen on the BIOS display)

  1. Adjust the valve on the audit adapter to allow air to flow to the instrument. Press and hold the STOP/RESET key on the BIOS until the BIOS screen shows:

     Flow> L OFF
     Average> L #
     Number in Average ^

  2. Press and hold the READ/AUTO key on the BIOS until you can hear the flow cell moving up and down. Allow the BIOS to count through several 1-10 sequences. When value3 reaches "10" again, write down value2 on the flow audit worksheet, where value1 is the current flowrate (LPM), value2 is the current average flowrate (LPM), and value3 is the current measurement number (out of 10) used to calculate value2.

Flow> value1
Average> value2 value3
Number in Average ^

3. Repeat this for 9 more cycles and fill out the worksheet. Reset the BIOS. Reattach the cyclone to the inlet. Remove the audit adapter, wipe off the inlet tubing, apply a thin layer of high vacuum grease to the instrument inlet, and reattach the cyclone.

- Compare OC/EC to BIOS by calculating a percent difference

  Average BIOS flow = Sum of the 10 BIOS readings / 10
  Adjusted average BIOS flow = Average BIOS flow x Ratio of STP to ambient
  Delta = Average adjusted BIOS flow - Instrument flow with BIOS attached
  % Difference = Delta / Average adjusted BIOS flow

- Press **ESC** to return to the service menu.
  - If returning the OC/EC to operation, down arrow to Exit Service Mode and press **ENTER**. Press the **RUN/STOP** button.
  - If continuing on with the Concentration Audit, down arrow to Calibration/Audit, and press **F2: CO2 Cal** to enter the CO_2 Calibration menu. Skip the first two bullets of Task 3b.

Task 3b: Concentration audit

- If the OC/EC is not in Ready mode, press **Run/Stop** followed by **F1: Immed** to put into Ready mode immediately, **or F2: EndCyc** so that the current sample cycle will complete without interruption.
- Once in Ready mode, press **MENU**, down arrow to the Service Mode option, press **ENTER**, press **F4: Yes** to assure that you want to enter the Service Mode, down arrow to Calibration/Audit, and press **F2: CO2 Cal** to enter the CO_2 Calibration menu.
- Confirm that the CO_2 Low% and the CO_2 High% values match the tank concentrations. Note that 400 ppm and 2500 ppm equate to 0.040% and 0.250%, respectively. If not, use the arrow buttons, press **EDIT**, key pad in the proper numbers, and press **ENTER**.
- Press **F3: Audit**, check to see that all three calibration gas bottles are connected, and press **F1: Yes**. The concentration audit will proceed by individually injecting CO_2 free air, low concentration CO_2, and high concentration CO_2 into the sensor generating calibration constants C1, C2, and C3. Each gas has a 90 second stabilization time and a 600 second sample time.
- After the audit is complete, press **F4: Data** and record the values for C1, C2, and C3 in the spaces provided on the worksheet.
- Calculate observed tank concentrations as shown below and record on the worksheet. The system volume may vary amongst instruments. The system volume can be obtained from the CO_2 Calibration Menu.

Zero air (ppm)	= C1*Sys Volume*10^{-6}
CO2-Low (ppm)	= C2*Sys Volume*10^{-6}
CO2-High (ppm)	= C3*Sys Volume*10^{-6}

- Compare the observed and actual tank concentrations by calculating a percent difference and recording on the worksheet.

  Delta = Tank concentration - Observed tank concentration
  % Difference = Delta / Tank concentration

Zero air (ppm)	± 15 ppm
CO2-Lo (%)	± 5% of actual tank concentration
CO2-High (%)	± 5% of actual tank concentration

- To return to sample mode, press **ESC** twice to the Service Menu, down arrow to Exit Service Mode, press **ENTER**, and start the measurement cycle by pressing **RUN/STOP**.
- Notify the field manager if the zero or percent difference is out of tolerance.

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Instrument:	Rupprecht & Patashnick OC/EC Series 5400
Worksheet:	Task 1 - Check for instrument errors in RunDef screen and Status screen (weekly)
Site Code:	

Date		/ /	/ /	/ /	/ /	/ /
Field Tech						
Instrument SN						
INITIAL CHECKS:						
DAS clock (PST)		: :	: :	: :	: :	: :
OC/EC clock (PST)		: :	: :	: :	: :	: :
1.) CHECK: RUN DEFINITIONS						
Parameter	Acceptable range					
Collection	1 hour					
Base Time	00:00					
Base Temp	50C					
ABurn Temp	750C					
ExtST Temp	0C					
Coll Flow	16.7 LPM					
Analysis Type	Reg					
P1	0					
P2	0					
P3	275C					
PF	750C					
D1	0					
D2	0					
D3	300s					
DF	360s					
ERRORS:						
Date / Time / Error Code						
Comments						

Instrument:	Rupprecht & Patashnick OC/EC Series 5400
Worksheet:	Task 3 - System audits (monthly)
Site Code:	

Date	/ /	/ /	/ /
Field Tech			
Instrument SN			
INITIAL CHECKS:			
Time			
DAS clock (PST)	: :	: :	: :
OCEC clock (PST)	: :	: :	: :
3) SYSTEM AUDITS			
Start time	: :	: :	: :
Stop time	: :	: :	: :
Flow audit			
T (K) = T (C) + 273.15			
P (mm Hg) = P (in Hg) x 25.4 = P (mb) x 0.75			
Ratio of STP to ambient conditions = 273.15 x P (mm Hg) / 760 / T (K)			
Adjusted average BIOS flow (LPM) = Average BIOS flow (LPM) x Ratio of STP to ambient conditions			
Delta (LPM) = Adjusted average BIOS flow (LPM) - Instrument flowrate with BIOS attached (LPM)			
% Difference (%) = 100 x Delta (LPM) / Adjusted average BIOS flow (LPM)			
BIOS model / SN	40DCL /	40DCL /	40DCL /
Ambient conditions			
Temperature (C) / Temperature (K)	/	/	/
Pres (in Hg or mb) / Pres (mm Hg)	/	/	/
Ratio of STP to ambient conditions			
Start date (PST) / Time	/	/	/
Instrument flowrates (LPM)			
Flow with cyclone (LPM)			
Flow with BIOS attached (LPM)			
Flow with adaptor set to zero (LPM)			
BIOS flowrates (LPM) / Time			
1st BIOS flow (LPM) / Time	/	/	/
2nd BIOS flow (LPM) / Time	/	/	/
3rd BIOS flow (LPM) / Time	/	/	/
4th BIOS flow (LPM) / Time	/	/	/
5th BIOS flow (LPM) / Time	/	/	/
6th BIOS flow (LPM) / Time	/	/	/
7th BIOS flow (LPM) / Time	/	/	/
8th BIOS flow (LPM) / Time	/	/	/
9th BIOS flow (LPM) / Time	/	/	/
10th BIOS flow (LPM) / Time	/	/	/
Stop date (PST) / Time	/	/	/
Compare OCEC to BIOS			
Average BIOS flow (LPM)			
Adjusted average BIOS flow (LPM)			
Delta (LPM)			
% Difference (%)			
Compare OCEC to Setpoint			
Flowrate setpoint for OCEC	16.67 LPM	16.67 LPM	16.67 LPM
Current OCEC flowrate (LPM)			
OCEC flow ± 0.5 LPM of setpoint?	Yes / No	Yes / No	Yes / No
Concentration audit			
Conc entration = constant x 1,000,000 / 106 (ppm)			
% Difference - (Target concentration - measurement concentration) / Target concentration x 100%			
Measurements			
C1 zero air			
C2 low			
C3 high			
Concentration calculations			
Zero air conc 0 ppm			
Low conc 405 ppm			
High conc 2401 ppm			
% Difference calculations			
Zero air conc +/- 25ppm			
Low conc +/- 5%			
High conc +/- 5%			
Comments			